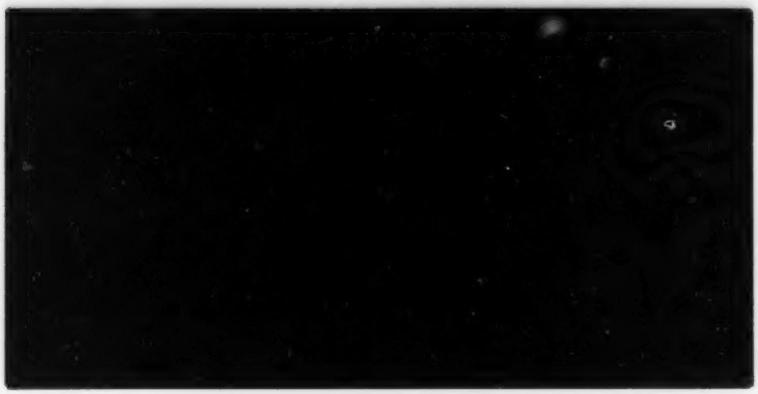
REPORT 36



SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION

DU MILIEU PEDOLOGIQUE

ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

100-05262/

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

RED CLOVER COVER CROP STUDIES
1987 - 1990

FINAL REPORT

January, 1992

Prepared by:	CONSERVATION MANAGEMENT SYSTEMS A Division of ECOLOGISTICS LIMITED, Lucan, Ontario
Under the Direction of:	ECOLOGICAL SERVICES FOR PLANNING LIMITED, Guelph, Ontario - Subprogram Manager For TED
On Behalf of:	AGRICULTURE CANADA RESEARCH STATION, HARROW, ONTARIO N0R 1G0

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ABSTRACT

The Effect of Time and Method of Control of a Red Clover Crop
on the Growth and Yield of Corn

In 1987-90 seven trials were conducted in Middlesex and Huron Counties in southwestern Ontario to study the effect of time and method of control of a red clover cover crop on the growth and yield of corn. Drought conditions during late spring and summer in 1988-89 affected the performance of the cover crop and main (corn) crop. Excessively moist conditions in the spring of 1990 affected plant emergence and final plant stand especially on the spring tillage treatment.

Results from three years of study indicate that in general those treatments which included the use of a mechanical method for controlling red clover resulted in grain corn yields approximately 11% higher than those achieved with the average no-till treatments, although the effect was not always statistically significant. However, this may be related to the previous crop stubble. Those sites which had red clover underseeded to winter wheat reported the greatest reduction in grain corn yield under no-till conditions compared to sites which had oats or oats and barley as the stubble crop. Under mechanical methods of red clover control the amount of soil surface residue cover left after planting was unacceptable from an erosion control standpoint. The chemical kill treatments provided somewhat lower corn grain yield with excellent residue cover remaining after planting. The mechanical kill treatment using the chisel plough produced yields which were similar to the October chemical kill treatments and may be used as an alternative to using the moldboard plough.

The amount of dry matter collected from each of the treatment plots was related to the date and method of control of the red clover. The chemical treatment applied in May recorded the greatest amount of dry matter after planting followed by the April timing whereas the least amount (if any) was collected on the moldboard plough treatments.

Results of the rainfall simulation indicated that the mechanical kill treatments (moldboard and chisel plough) recorded significantly higher runoff volumes, soil losses as well as total phosphorus losses compared to either of the chemical kill treatments (October and April). The difference in the results obtained for the chemical kill treatments for the above parameters were not significant indicating that the time of the red clover kill did not affect the erosion control of these treatments. In addition, no significant differences between the chisel and moldboard plough treatments were reported for these parameters.

ACKNOWLEDGEMENTS

The following study was funded by Agriculture Canada through the Technology Evaluation and Development (TED) sub-program of the Soil and Water Environmental Enhancement Program (SWEEP).

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1.0 INTRODUCTION AND OBJECTIVES

It is our understanding that the Technology Evaluation and Development (TED) subprogram of SWEEP was established to facilitate the evaluation of existing technologies and the adaptation of such technologies for soil conservation and phosphorus (P) load reduction purposes. It is intended that TED-sponsored investigations would be undertaken mainly at field-scale and within commercial farming operations.

An important objective of this subprogram is the involvement and close cooperation of the farming community in the process of developing and refining technologies and systems. Through this involvement it is expected that the results of TED-sponsored research will be directly applicable to important problems and needs faced by farmers as they attempt to deal with soil degradation. Rapid adoption of such technologies will be necessary for SWEEP to realize its phosphorus reduction goals within the specified time frame.

Because of the high proportion of P loss that occurs during spring runoff, especially in row crop fields, it is desirable to achieve a temporary vegetative cover over winter and during spring runoff to hold the soil in place. Added organic material and possibly nitrogen from cover crops may also benefit soil stability and productivity.

A number of farm operators have been experimenting on their own with a variety of cover crop species and management methods. Of note is the work of several operators in the Rondeau Bay watershed over the past half dozen or so years. For row crops grown in highly erodible, rolling landscapes, as happens in that watershed, winter cover is essential. In many cases residue from the previous crop is not acceptable or adequate to keep the soil from eroding.

Conditions such as those found in the Rondeau Bay watershed occur on many other landscapes across southwestern Ontario, with their long steep slopes and row crops which occupy a high proportion of the cultivated land. It is clear that wider scale use of cover crops could have a significant impact on SWEEP's P reduction target.

While efforts by innovative conservation farmers to develop effective cover crop management systems have made significant progress, numerous questions regarding the best species/varieties, application and kill methods and timing remain to be answered. It is the intent of the TED cover crop studies to address these questions.

In order to make relatively rapid progress in our understanding of this area and the subsequent adoption of suitable practices, it is important to work with existing crops where the basic management techniques are widely known and practised. It is also important to work with those alternatives that provide an adequate level of erosion control and are relatively inexpensive to implement.

While the use of cover crops is most conveniently associated with a no tillage cropping system it is recognized that many Ontario producers will adopt some form of a reduced or minimum tillage system. With this in mind, the cover crop studies should be of value to users of either type of system.

1.1 Purpose of the Cover Crop Research

Our interpretation of the terms of reference indicated that the initial work was to serve as a prelude to field scale testing, i.e. to carry out investigations that would assist with the decisions about which longer-term, field-scale studies should be undertaken. Plot or field strip experiments were desired in the field season.

The initial work was expected to determine:

a) which cover crops can be grown effectively in corn-bean rotations under various soil (and climatic) conditions;

b) optimum techniques for establishing and killing cover crops prior to planting primary crops;

c) the effect of cover crops on the following crop yield response, weed pressure, harvesting and related management operations.

1.2 Rationale for Red Clover Cover Crop Research

In many areas of southwestern Ontario a commonly used crop rotation includes grain corn, soybeans or white beans, and winter or spring cereals. This combination of crops is likely to continue in the future. Underseeding red clover with a winter or spring cereal crop is a common practice.

Under current management practices the majority of the red clover is ploughed down using the moldboard plough in late October and November. This leaves the soil exposed during a time when the erosive action of wind and water can cause the most damage. Through the use of spring tillage or no tillage systems the benefits of the red clover could be expanded to include those associated with winter cover crops.

The time at which a cover crop is killed can affect the growth of the following crop depending on the circumstances involved. Excess loss of soil moisture especially in a dry spring, and allelopathic effects are two examples of problems that may arise. The purpose of the following study was to determine the effect of time and method of control of a red clover crop on the growth and yield of corn.

1.3 Objectives of Red Clover Cover Crop Research

i) to determine the effect of time and method of control of a red clover cover crop on the amount of residue and/or live plant cover remaining on the soil surface between harvest and the establishment of the next crop canopy;

ii) to quantify the amount of above-ground red clover plant dry matter present at various times in the growing season in relation to time and method of control of a red clover cover crop;

iii) to determine the effect of time and method of control of a red clover cover crop on the growth and yield of grain corn;

iv) to prepare preliminary recommendations on the management of a red clover cover crop with regard to time and method of elimination.

2.0 LITERATURE REVIEW

Cash crop producers in southwestern Ontario are presently showing an increased interest in soil conservation as the effects of soil erosion become more widely known. The vulnerability of soils to water erosion is often increased during the springtime. Estimates of the contribution of snow-melt runoff from plots maintained bare during the entire year to total annual runoff range from 10% to 88% (Kirby and Mehuys, 1987). Under normal cultural practices (presence of a crop during at least part of the season) the relative contribution of winter soil loss would be greater. These estimates are mainly affected by soil type and slope gradient (Kirby and Mehuys, 1987). van Vliet and Hall (1981) estimated that about 10% of the annual soil erosion due to water occurs in the spring period in southern Ontario. However, Dickinson *et al.* (1975) suggested that 50% of the annual sediment load of rivers of the same area took place during the spring runoff period. These values demonstrate the need tor good ground cover during the early spring.

The use of cover crops as a method of soil erosion abatement has long been established. Rye (*Secale cereale* L.) has traditionally been used as a break and cover crop on tobacco soils of southwestern Ontario. However, some current green manuring practices deserve investigation so that they may be adapted to contemporary cropping systems. The use of underseeded red clover (*Trifolium pratense* L.) grown as a plough down crop is examined. The benefits and shortcomings, as well as ways the system may be potentially modified to better suit modern farming in southwestern Ontario, are covered in this report. The following review discusses the role of red clover as a potential winter cover crop.

2.1 Red Clover Cover Crop

A common cropping practice in southwestern Ontario is the underseeding of red clover into spring or winter cereal stands. The red clover growth is normally ploughed with a moldboard plough late in the fall before the soil freezes. This, however, renders the soil susceptible to the action of water erosion in the late autumn and especially in the early spring when snow is melting. Maintaining red clover over winter and killing it in the spring could lead to a reduction in the amount of soil lost before the next crop.

The spring removal of red clover leads to greater dry matter accumulation which tends to favour an increased nitrogen supply to the next crop (Smith *et al.*, 1987). The same study

reported top growth of winter annual cover crops to be generally low in phenolic compounds which are one of the principal groups of phytotoxic compounds. Being high in protein content and low in lignin content, legume shoot material is rapidly degraded. Stott and co-workers (1983) measured approximately a 50% conversion of plant protein carbon to CO_2 within two weeks. However, there is evidence that decomposition and mineralization of nitrogen are slower for surface residue (Brown and Dickey, 1970 cited by Smith et al., 1987). This is generally attributed to lower moisture and nutrient availability for decomposition at the surface. Delaying ploughing or herbicide killing of red clover until spring would thus seem to contribute more nitrogen to the next crop than fall ploughing.

Vyn (1987), however, noted that corn yield was reduced when seeded with zero tillage into red clover that had been chemically killed prior to corn sowing. The yield losses were attributed to poor stands which were caused by insect injury from slugs (Agriolimax reticulatus Muller) and potato stem borers (Hydraecia micace Esper). This insect damage was observed during only one of the three years of the research and did not affect other treatments (corn, soybean and barley as crops preceding corn) under investigation except alfalfa/timothy, which did not reduce corn yields as extensively as red clover. Had the red clover and alfalfa/timothy been chemically controlled the previous fall instead of just before corn planting, the corn establishment might have been more consistent (Vyn, 1987).

Little information deals specifically with red clover removal methods. Smith et al. (1987) mentioned that an application of gramoxone and a triazine herbicide would adequately kill a winter legume cover crop. Vyn (1987) used a mixture of atrazine, 2,4-D and oil concentrate (2.5 kg, 1.0 kg, 10 l/ha) applied just prior to corn planting. However, application of 2,4-D and oil concentrate alone has successfully killed red clover as long as the plants were actively growing (Vyn, 1991 personal communication).

Relatively few studies are available in the literature which deal directly with the management of red clover as a ploughdown crop preceding corn. Most of the research on winter legumes grown for green manure has identified the benefits of nitrogen contributions from the legume to the subsequent crop. Studies in the United States have dealt with species that cannot grow satisfactorily in Ontario and have emphasized timing and method of establishment rather than focusing on optimal removal techniques. Research should be undertaken to determine when and how a red clover cover crop should be removed in southwestern Ontario for optimal erosion control, legume nitrogen utilization by corn and corn grain yields.

3.0 DEVIATIONS FROM THE WORK PLAN

In year one of the red clover cover crop study three sites were initiated by Conservation Management Systems (CMS). Two of the sites were located on cereal underseeded to red clover, the third site was located on a second year red clover mixture hay field. In the second and third year of the study the sites were located on cereal fields underseeded to red clover. Due to the above variation in field history, the third site of year one is not included in the analysis over locations, but is presented alone.

Dry matter samples were taken in the spring and summer of 1989 at sites 3 and 4 but were misplaced during processing at the University of Guelph. The results are therefore not available.

4.0 MATERIALS AND METHODS

4.1 Location and Characterization of Treatment Plots

The red clover cover crop trials were located at seven different sites over a three year period. Location of each site was as follows:

Site	Year	Lot	Concession	Township	County
1	1	76	Maitland	Goderich	Huron
2	2	70+71	Maitland	Goderich	Huron
3	1	23	21	West William	Middlesex
4	2	6+7	14	Hullett	Huron
5	3	6+7	14	Hullett	Huron
6	3	20	16	Goderich	Huron
7	1	2+3	8	Ashfield	Huron

Soil samples were taken to determine soil texture and fertility levels at each site. The samples were analyzed according to the standard procedures used by the Department of Land Resource Science, University of Guelph. See below for site specifications.

Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
P (mg/kg)	33	25	24	33	24	22	12
K (mg/kg)	165	174	176	120	112	81	179
Mg (mg/kg)	305	457	363	533	301	301	454
Ca (mg/kg)	2640	2830	2850	2790	2730	2910	1730
pH	7.4	7.4	7.1	7.4	7.6	7.3	6.2
% Sand	33.6	30.1	42	18.0	32.3	45.4	22.2
% Silt	44.2	44.8	39.4	57.6	51.0	41.0	37.4
% Clay	22.1	25.2	18.6	24.4	16.7	13.5	40.4
Texture	Loam	Loam	Loam	Silt Loam	Silt Loam	Loam	Clay

4.2 Experimental Design and Analysis

The trials were set up as a randomized complete block design consisting of four replications. Each replicate consisted of six (6) different treatments:

Treatment	Year 1	Year 2	Year 3
1 - chemical kill	October 1987	October 1988	October 1989
2 - chemical kill	April 1988	April 1989	April 1990
3 - chemical kill	May 1988	May 1989	May 1990
4 - mechanical kill with moldboard plough	November 1987	November 1988	November 1989
5 - mechanical kill with moldboard plough	April 1988	April 1989	April 1990
6a - mechanical kill with chisel plough	November 1987 (Sites 1 and 7)	November 1988 (Site 4)	November 1989 (Site 5 and 6)
6b - chemical kill	September 1988 (Site 3)	September 1987 (Site 2)	

The dimensions of each plot were adjusted to fit the cooperator's equipment with plots ranging in size from 3.0m by 9.1m to 4.6m by 9.1m.

Analyses of variance were calculated for each parameter for each location and where appropriate, sites with identical treatments were combined. Contrasts were performed to further investigate differences among the treatments. As explained in Section 2.0 the data for site 7 were analyzed as an individual site due to variation in previous cropping practices.

4.3 Agronomic Practices

In the late summer of 1987 (year 1), 1988 (year 2), and 1989 (year 3) the red clover cover crop studies were initiated by CMS. The sites were located in underseeded cereal stubble fields with the exception of site 7 which was located in a second year red clover mixture hay field.

Atrazine, 2,4-D, corn oil and water were used at 6.0 l/ha, 1.25 l/ha, 2.5 l/ha and 176.3 l/ha, respectively for the chemical treatments in the fall. For the spring application of the herbicide the rate of 2,4-D was increased to 2.13 l/ha. This combination was applied to the plots using a backpack CO_2 sprayer with a hand held boom by CMS staff. Mechanical killing of the red clover was carried out using a moldboard plough or chisel plough owned and operated by the cooperator.

In the spring, chemically treated plots were planted no-till while mechanically treated plots were planted to corn using the same planter. The specifications for each site are given in Table 1.

Cooperators applied pre-emergence herbicides for annual grass control plus post-emergent herbicides for broadleaf weeds. In addition CMS staff used chemical and manual methods throughout the spring and summer to control weeds and red clover regrowth in the plots that were not controlled by previous herbicides.

Maximum, minimum and mean monthly temperatures and monthly precipitation are summarized in Appendix A. Information for these tables was obtained from the Atmospheric Environment Service, Environment Canada Thedford, Brucefield, Lucknow and Blyth stations.

4.4 Measurements

4.4.1 Cover Crop Establishment and Development

i) Soil Residue Cover

A rope with knots at 15 cm intervals was used to make four counts of residue cover per plot. Residue cover was determined by counting each knot on the rope that touched a piece of residue. The knotted rope was positioned diagonally across the plot. Two counts were taken from the top right to bottom left corners and two from the top left to the bottom right corners. Data were adjusted to percent residue cover.

ii) Red Clover Dry Matter

Live and/or dead red clover plants from a 0.25 m^2 area were clipped at ground level, separated from the cereal stubble and placed in a bag and frozen. The plants were subsequently dried to a constant weight in a forced-air dryer. The dried weight values were adjusted to kg dry matter/ha.

Table 1: Cropping and Tillage Information for the Seven Sites Involved in the Red Clover Cover Crop Study, 1987-90.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Previous Cropping Information							
- Crop	Winter wheat	Winter wheat	Winter wheat	Oats	Oats	Barley/oats	Red clover hay
- Variety				Donald	Donald	Leger/Donald	mixture
- Straw management		baled (?)		baled	baled	baled	hay
- Cover Crop	Red clover	Red Clover	Red clover	Red Clover	Red Clover	Red Clover	as above
Current Cropping Information							
- Secondary tillage (mechanical treatments only)	Cult (2x)	Cult (2x)		None	Shallow Cult (1x)	Cult (2x)	None
- Crop	Corn	Corn	Corn	Corn	Corn	Corn	Corn
- Variety	Pioneer® 3790	Pioneer® 3790		Pioneer® 3790	G.L.® 420	Pioneer® 3790	
- Seeding date	May 12/88	May 6/89	May 6/88	May 16/89	May 13/90	May 8/90	May 5/88
- Seeding rate (s/ha)	64244	64244	60294	73879	68689	69189	69681
- Row width (cm)	76.2	76.2	91.4	76.2	76.2	76.2	76.2
Fertilizer							
- At plant (kg/ha)	213 kg 10-23-26	213 kg 10-23-26	178 kg 7-39-18 44.5 kg N	89 kg 7-31-22 32 kg actual N	44.5 kg 11-50-0 40 kg actual N	178 kg 4-22-35	56 l/ha 8-27-3
- Post plant (kg/ha)	98 kg actual N	98 kg actual N	44.5 kg N	98 kg actual N	89 kg actual N	89 kg actual N	67 kg N 53 kg P 71 Kg K
Non-test Pesticide							
- Pre-plant	Roundup®					Roundup®	Atrazine
- At Plant							
- Post Plant	Dual® Atrazine	Atrazine Dual® Banvel® 2,4-D	Atrazine	Banvel® Dual®	Marksman®	Dual® Banvel® Bladex®	2,4-D
Plant Equipment							
- Planter type	White® 5100	White® 5100	John Deere®	John Deere® 7000	John Deere® 7000	White® 5100	
- Attachments	Ripple coulters plus notched trash whippers	Ripple coulters plus notched trash whippers		2-2" Rawson® no-till coulters	2-2" Rawson® no-till coulters	Ripple coulters plus notched trash whippers	

4.4.2 Main Crop Establishment and Development

i) Corn Plant Emergence

Corn emergence was measured as the number of emerged plants per one square metre. Three subsamples per plot were collected in this manner. These data were collected approximately 14 and 21 days after the planting (DAP) date and are presented as the number of plants emerged per hectare.

ii) Corn Plant Height

The height of individual corn plants within one square metre was recorded at three different locations within each plot. Plant heights were taken from the ground to the top of the longest, fully extended leaf on the plant. Measurements were taken to the nearest half centimetre at the 2-3 leaf and 6-7 leaf stages of growth.

iii) Corn Plant Silking

Ten consecutive corn plants from the four centre rows of each plot were visually assessed for the emergence of silk hair from the ear of each plant. These values were presented as days to 50 % silking.

iv) Corn Yield and Associated Factors

The ears from all the plants along a 5.0 metre length of the two centre rows (sites 3 and 7) or the ears from all the plants along a 2.5 metre length of the four centre rows (sites 1, 2, 4, 5, and 6) were hand harvested and weighed (TC). Ten average ears were then selected, weighed (FC) and dried to a constant weight in a forced-air dryer, at 80°C, for about four days. The dried ears were subsequently weighed (DC) and shelled.

The shelled grain was again weighed (G). The final grain yield per sample, adjusted to kilograms per hectare at 15.5 percent moisture content, was calculated using the following equation:

$$\text{Yield} = \frac{TC \times G}{FC}\ \frac{kg}{7.62\ m^{2*}} \times \frac{10^4\ m^2}{ha} \times \frac{100}{84.5}$$

* note that sites 1, 2 and 4-7 used this area whereas site 3 used 9.14 m^2.

From the same data the percent moisture content at harvest was calculated as follows:

$$\%\ \text{Moisture Content} = \frac{FC - DC}{FC} \times 100$$

The number of plants within the harvested area was counted (in 1990 only) to give the final corn plant population. The data are presented as the number of corn plants per hectare.

5.0 RESULTS AND DISCUSSION

5.1 Cover Crop Results

i) Soil Residue Cover

In April prior to spring treatment application and planting, all chemical treatment plots plus the April moldboard treatment plots recorded values of 85% or greater soil surface residue cover, which were significantly greater than the remaining treatment plots (Table 2). The amount of soil surface residue measured on the fall moldboard treatment plots in April ranged from 2 to 11% depending on the site location. Site 4 recorded a soil surface residue level of 84% on the November chisel plough treatment plots whereas the remaining sites (3, 5, 6 and 7) recorded levels ranging between 53% and 59%.

When data for after planting soil surface residue levels from sites with the same treatments were combined the interactions of treatment by location were significant, indicating that treatments did not have the same effect on residue levels over site locations (Tables 3 and 4). Contrasts comparing the treatments showed that the chemical kill treatment plots had significantly more residue remaining after planting than the mechanical kill treatment plots at all sites (Tables 5 and 6). Average soil surface residue levels for the mechanical kill treatment plots ranged form 3 to 26% while average residue levels for the chemical kill treatment plots ranged from 33 to 84%.

There were no significant differences found for the after planting soil surface residue levels when the fall and spring moldboard plough treatment plots were compared for all sites although significant differences were found when comparing the fall and spring chemical treatment plots with the exception of site 3 (Tables 5 and 6). The soil surface residue level on the spring chemical kill treatment plots averaged 12.6% greater than residue levels measured on the fall chemical kill treatment plots for sites 1, 2, 4, 5, 6 and 7 while a difference of 3.5% was reported at site 3. Only three of the sites (1, 4 and 5) reported significant differences between the April and May chemical kill treatment plots with regard to soil surface residue levels remaining after planting.

As shown in Table 5 the September chemical kill treatment plots at sites 1 and 2 left significantly less residue after planting than the October chemical kill treatment plots. A

Table 2: Mean Early Spring Soil Surface Residue Cover for the Red Clover Cover Crop Studies Located in Huron and Middlesex Counties, 1987-90.

Treatment	Early Spring Soil Surface Residue Cover (%)						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	96 a*	99 ab	95 a	97 a	87 b	97 a	99 a
Chemical kill - April	98 a	100 a	97 a	98 a	93 ab	98 a	99 a
Chemical kill - May	98 a	100 a	97 a	98 a	90 ab	98 a	99 a
Moldboard Plough - November	11 c	6 c	2 c	7 c	11 d	6 c	2 c
Moldboard Plough - April	99 a	100 a	98 a	99 a	93 a	98 a	99 a
Chisel Plough - November			53 b	84 b	59 c	55 b	50 b
Chemical kill - September	85 b	98 b					
Coefficient of variation	3.8	0.9	3.5	2.5	5.5	2.8	4.6

* Values within the same column followed by the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

Table 3: Mean Squares of Soil Surface Residue Levels After Planting, Corn Grain Yield and Moisture Content at Harvest for Treatments Combined Over Locations for Those Sites Having the Chemical Kill Treatments in September as Treatment Six (Sites 1 and 2). Red Clover Cover Crop Study, 1987-90.

Treatment	df	Residue Level After Planting	Corn Grain Yield	Moisture Content
Location	1	585.141**	12290833.912*	16.709NS
Rep + Rep x Location	6	16.294	1648419.744	3.087
Treatment	5	8964.300**	1943807.650**	15.672**
Location x Treatment	5	90.845**	457351.772NS	1.624NS
Error	30	19.233	402554.526	1.149
Total	47	9675.813	16742967.604	38.241

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.
NS Not significant at the 0.05 level of probability.

Table 4: Mean Squares of Soil Surface Residue Levels After Planting, Corn Grain Yield and Moisture Content at Harvest for Treatments Combined Over Locations for Those Sites Having the Chisel Plough Applied in November as Treatment Six (Sites 3-6). Red Clover Cover Crop Study, 1987-90.

Treatment	df	Residue Level After Planting	Corn Grain Yield	Moisture Content
Location	3	5614.918**	66531644.032**	696.060**
Rep + Rep x Location	12	16.460	892894.088	13.572
Treatment	5	14073.171**	250410.846NS	4.316NS
Location x Treatment	15	480.207**	1002878.843*	13.666NS
Error	60	64.135	534834.263	8.235
Total	95	20248.891	69212662.072	735.849

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.
NS Not significant at the 0.05 level of probability.

Table 5: Mean Soil Surface Residue Levels After Planting for Those Sites Having the Chemical Kill Treatment in September as Treatment Six (Sites 1 and 2). Red Clover Cover Crop Study, 1987-90.

Treatment	Soil Surface Residue Level After Planting (%)	
	Site 1	Site 2
Chemical kill - October	75	66
Chemical kill - April	81	72
Chemical kill - May	90	75
Moldboard Plough - November	12	4
Moldboard Plough - April	13	6
Chemical kill - September	52	57
Probability that the Difference Between Means of Specified Orthogonal Contrasts is Zero		
Fall vs. Spring Moldboard	NS	NS
Mechanical vs. Chemical kill	**	**
April vs. May Chemical kill	*	NS
September vs. October Chemical kill	**	**
Fall vs. Spring Chemical kill	**	**

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.
NS Not significant at the 0.05 level of probability.

Table 6: Mean Soil Surface Residue Cover After Planting for Those Sites Having the Chisel Plough in November as Treatment Six (Sites 3-7). Red Clover Cover Crop Study, 1987-90.

Treatment	Soil Surface Residue Level After Planting (%)				
	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	82	71	52	28	26
Chemical kill - April	78	76	57	38	33
Chemical kill - May	93	83	63	44	41
Moldboard Plough - November	9	6	4	1	3
Moldboard Plough - April	13	8	2	2	7
Chisel plough - November	57	12	18	3	17
Probability that the Difference Between Means of Specified Orthogonal Contrasts is Zero					
Fall vs. Spring Moldboard	NS	NS	NS	NS	NS
Moldboard vs. Chisel Plough	**	**	**	NS	*
Fall vs. Spring Chemical kill	NS	**	**	**	*
Mechanical vs. Chemical kill	**	**	**	**	**
April vs. May Chemical kill	NS	**	*	NS	NS

*, ** Significant at the 0.05 and 0.01 levels of probability, respectively.
NS Not significant at the 0.05 level of probability.

difference of 23% residue was reported at site 1 while site 2 had a difference of only 9% residue which may be attributed to differences in the initial stand of red clover.

With the exception of site 6, the chisel plough treatment plots had significantly more residue than the moldboard plough treatment plots for those sites which included the chisel plough as a treatment (Table 6). Average soil surface residue levels measured after planting for the moldboard plough treatment plots varied between 3 to 11% while residue levels for the chisel plough treatment plots were from 12 to 57%. There was little difference between the chisel and moldboard treatment plots for the after planting soil surface residue levels at site 6.

The difference in the after planting residue levels may be attributed to various secondary tillage carried out by the cooperators (conventional plots only), moisture conditions (which affects red clover decomposition) and timing of data collection.

ii) Red Clover Dry Matter

The amount of red clover dry matter remaining in early spring and after planting for each treatment was directly related to the date at which the red clover cover crop was killed (Table 7). The chemical kill in May treatment had the greatest amount of dry matter while the mechanical kill using the moldboard plough in November had the least.

iii) Rainfall Simulation

Ecological Services for Planning Ltd. (ESP) carried out rainfall simulation work on site 4 (1989) and site 6 (1990) using the Guelph Rainfall Simulation II as part of another TED research contract. The methods followed by ESP for this work are outlined in the Rainfall Simulation 1990 and 1991 reports (ESP, 1990, 1991).

The rainfall simulation work was conducted shortly after planting at each of the sites using two of the chemical kill treatment plots (October and April) and both moldboard plough treatment plots (November and April). In addition, the chisel plough treatment plot was included in the rainfall simulation at site 6. Data collected included slope, residue cover, runoff volume, soil loss and total phosphorus loss.

Table 7: Red Clover Dry Matter for the Red Clover Cover Crop Studies Located in Huron and Middlesex Counties, 1987-90.

Treatment	Early Spring Red Clover Dry Matter (kg/ha)		After Planting Red Clover Dry Matter (kg/ha)	
	Site 5	Site 6	Site 1	Site 3
Chemical kill - October	960 cd*	1500 bc	1324 b	489 c
Chemical kill - April	3340 a	3520 a	1436 b	1275 b
Chemical kill - May	3380 a	2080 b	2540 a	2252 a
Moldboard Plough - November	160 d	0 d	120 c	0 c
Moldboard Plough - April	2780 ab	3400 a	407 c	393 c
Chisel Plough - November	1600 bc	480 cd		445 c
Chemical kill - September			224 c	
Coefficient of Variation	39.4	41.9	42.9	45.0

* Values within the same column followed by the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

Each site was located on a loam soil surface texture with a pH of 7.3 (site 4) and 7.5 (site 6). The organic matter content and slope of the surface varied somewhat between sites with site 4 having an organic matter content of 5.6% and a uniform slope of 9% whereas site 6 had an organic matter content of 3.6% and the slope varied from 3.0 to 6.2%. The slopes of the chemical kill plots were significantly less than those of the mechanical kill plots at site 6 (ESP, 1991) possibly affecting the results.

There was greater soil surface residue cover at site 4 than at site 6 on the chemical treatment plots with levels of 67% and 92% (site 4) and 46% and 61% (site 6) for fall and spring chemical treatment plots, respectively. The moldboard plough treatment plots averaged 6% soil surface residue with no differences between the timing of treatment implementation (fall vs. spring). The average soil surface residue level for the chisel plough treatment plot was 18% at site 6.

The amount of runoff collected from the mechanical treatment plots was considerably greater than the volume of runoff from the chemical treatment plots. The average runoff volume for the mechanical treatment plots for site 4 was 6.9 l/m^2 and 15.6 l/m^2 for site 6 compared to 3.4 l/m^2 and 4.9 l/m^2 for the chemical treatment plots. The variation in runoff volumes between the sites may partially be attributed to differences in slope and residue cover.

The method of eliminating the red clover cover crop had a significant effect on the amount of soil that was lost. Where the red clover had been chemically killed the soil loss was reduced by 85% on site 4 and 91% at site 6 compared to the mechanically killed red clover plots.

The total phosphorus concentration in the sediment (1.2 grams phosphorus per kilogram) was similar for all treatments at site 4. The chemically treated plots had a slightly higher concentration of phosphorus (1.4 g/kg) in the sediment than did the mechanically treated plots (1.1 g/kg) at site 6. Since runoff and soil loss were greater for the mechanical than for the chemical treatment plots, the total amount of phosphorus lost was also greater. Phosphorus losses were six to nine times greater for the mechanical method of control of the red clover than for the chemical control methods.

5.2 Main Crop Results

i) Corn Plant Emergence

The interaction of treatment by locations when sites 1 and 2 were combined was found not to be significant for plant emergence data collected 14 DAP, thus the combined site data are presented for this parameter. Significant interactions of treatment by location were found for the plant emergence data collected 14 and 21 DAP when sites 3-6 were combined and for plant emergence at 21 DAP when sites 1 and 2 were combined (data not shown).

The chemical kill in October treatment plots recorded 67000 plants/ha at 14 DAP which was significantly more than the chemical kill in May (60000 plants/ha) and moldboard plough in April (59000 plants/m^2) treatment plots for the combined data from sites 1 and 2 (Table 8). The remaining treatments were not significantly different from these treatments. The lowest numbers of plants emerged per hectare at 14 DAP were recorded in the chemical kill in May treatment plots while the fall moldboard plough treatment plots recorded the greatest number of plants per hectare at sites 4, 5 and 6 (Table 8). At site 7 significantly more plants were counted in the fall moldboard plough treatment plots than in the chemical kill in April treatment plots at 14 DAP, with values of 60000 and 51000 plants/ha, respectively. The remaining treatments at site 7 recorded values between this range. No corn plants were emerged at 14 DAP at site 3.

As shown in Table 9, the difference between treatments for plant emergence at 21 DAP for sites 3 and 7 was not significant. The mechanical kill treatment plots reported a greater

Table 8: Mean Corn Plant Emergence 14 Days After Planting for the Red Clover Cover Crop Studies Located in Huron and Middlesex Counties, 1987-90.

Treatment	Corn Plant Emergence 14 DAP (plants/ha)					
	Sites 1 & 2	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	67000 a*	0**	64000 ab	30000 ab	65000 a	53000 ab
Chemical kill - April	60000 ab	0	68000 a	50000 a	63000 ab	51000 b
Chemical kill - May	60000 b	0	55000 b	25000 b	55000 b	57000 ab
Mb Plough - November	61000 ab	0	73000 a	54000 a	66000 a	60000 a
Mb Plough - April	59000 b	0	68000 a	31000 ab	64000 ab	58000 ab
Chisel Plough - Nov.		0	72000 a	42000 ab	59000 ab	54000 ab
Chemical kill - Sept.	63000 ab					
Coefficient of variation	10.2	NA	12.1	42.6	10.3	10.7

* Values within the same column followed by the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

** No plants emerged at this site 14 DAP.

NA Not applicable.

Table 9: Mean Corn Plant Emergence 21 Days After Planting for the Red Clover Cover Crop Studies Located in Huron and Middlesex Counties, 1987-90.

Treatment	Corn Plant Emergence 21 DAP (plants/ha)						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - Oct.	70000a*	71000abc	56000a	71000ab	46000bc	59000b	62000a
Chemical kill - April	62000b	62000c	58000a	67000b	53000ab	60000b	59000a
Chemical kill - May	63000b	63000bc	54000a	67000b	48000abc	63000ab	65000a
Mb Plough - Nov.	59000bc	72000ab	60000a	76000a	61000a	62000ab	62000a
Mb Plough - April	55000c	76000a	55000a	74000a	38000c	68000a	63000a
Chisel plough - Nov.			53000a	72000ab	52000abc	57000b	64000a
Chemical kill - Sept.	60000bc	73000a					
Coefficient of variation	5.5	9.0	13.3	6.5	19.8	8.4	15.8

* Values within the same column followed by the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

number of plants emerged than the chemical kill treatment plots at sites 2 and 4, but were not necessarily significantly different. At site 1 the chemical kill in October treatment plots recorded significantly more plants emerged (70000 plants/ha) than the remaining treatments (55000 - 63000 plants/ha).

The number of plants emerged at 21 DAP at sites 5 and 6 ranged from 38000 - 61000 plants/ha and 57000 - 68000 plants/ha respectively. The data collected at site 5 showed that the moldboard plough treatment performed in April had the lowest number of plants emerged which may have been attributed to the crusting of the soil surface as a result of excessive rains occurring just after planting.

ii) Corn Plant Height

A treatment effect on plant height was evident for sites 1 and 2 (results combined) as shown in Tables 10 and 11. At the 2 to 3 and 6 to 7 leaf stage the corn plants in the plots treated with the moldboard plough had the tallest plants with the chemical kill treatment plots following in descending order beginning with the earliest date of application (i.e. chemical kill in September).

The same trend as mentioned above occurred at sites 3 and 4 at the 2 to 3 leaf stage with the chisel plough treatment plots performing similar to the chemical kill in October treatment plots (Table 10). The ranking of treatments did not change at the 6 to 7 leaf stage for site 3. At site 4 the October chemical kill and chisel plough treatment plots measured at the 6 to 7 leaf stage reported the tallest corn plants followed by the chemical kill in April treatment plots (Table 11). The April moldboard treatment plots at site 5 produced the shortest plants compared to the remaining treatments. Since it is speculated that the emergence was affected by the crusted soil at this site it would also affect the growth rate. There was no significant differences among treatments at site 6 at either date.

At Site 7 corn in the chemical kill in May treatment plots were significantly shorter than the remaining treatments with the chemical kill in October plots producing the tallest plants at the 2 to 3 leaf stage (Table 10). At the 6 to 7 leaf stage there was no significant variation in corn plant height between treatments as shown in Table 11.

Table 10: Mean Corn Plant Height at the 2-3 Leaf Stage for the Red Clover Cover Crop Studies Located in Huron and Middlesex Counties, 1987-90.

Treatment	Corn Plant Height 2 - 3 Leaf Stage (cm)					
	Sites 1 and 2	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	14.0 bc*	14.1 ab	7.1 ab	8.3 ab	12.0 a	14.0 a
Chemical kill - April	13.0 cd	13.0 bc	6.9 b	8.9 ab	11.5 a	13.2 b
Chemical kill - May	12.2 d	11.6 c	5.9 c	9.1 a	11.2 a	12.6 c
Moldboard Plough - November	15.9 a	15.7 a	7.6 ab	8.9 ab	11.3 a	13.6 ab
Moldboard Plough - April	14.9 ab	14.6 ab	7.9 a	7.4 b	11.0 a	13.1 ab
Chisel Plough - November		13.7 b	7.2 ab	8.9 ab	11.8 a	13.8 a
Chemical kill - September	14.7 b					
Coefficient of variation	8.2	9.1	8.8	12.6	6.2	8.8

* Values within the same column followed with the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

Table 11: Mean Corn Plant Height at the 6-7 Leaf Stage for the Red Clover Cover Crop Studies Located in Huron and Middlesex Counties, 1987-90.

Treatment	Corn Plant Height 6 - 7 Leaf Stage (cm)					
	Sites 1 and 2	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	36.9 b*	40.0 b	44.3 a	28.2 ab	39.0 a	39.1 a
Chemical kill - April	32.2 c	37.1 b	42.8 ab	30.1 a	38.1 a	36.7 a
Chemical kill - May	32.5 c	30.8 c	41.2 b	31.0 a	36.6 a	36.3 a
Moldboard Plough - November	42.5 a	47.2 a	41.6 b	26.6 ab	37.7 a	36.7 a
Moldboard Plough - April	40.5 a	47.9 a	41.5 b	25.1 b	38.0 a	36.6 a
Chisel Plough - November		39.3 b	43.6 ab	28.9 ab	38.3 a	35.5 a
Chemical kill - September	36.7 b					
Coefficient of variation	7.5	10.3	4.2	11.5	6.1	11.8

* Values within the same column followed with the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

iii) Corn Plant Silking

In general the moldboard treatment plots reached 50% silking before any of the other treatments at sites 1, 2, 3, 4, 6 and 7 although there was no significance in the number of days to 50% silking at sites 1, 6 and 7 (see Table 12). The average advantage for using moldboard tillage was 2.1, 4.0 and 0.3 days for sites 2, 3 and 4, respectively. The opposite results were observed at site 5 where the November moldboard treatment plots took 91.5 days to reach 50% silking which was significantly longer than the October chemical kill

treatment plots (88.8 days). The remaining treatments achieved 50% silking between these dates. This difference may again be attributed to the delayed plant growth caused by the crusting of the soil surface.

A difference in the days to 50% silking between sites may reflect a difference in corn hybrid used, soil type or weather conditions.

Table 12: Days to 50% Corn Silking for the Red Clover Cover Crop Studies Located in the Huron and Middlesex Counties, 1987 - 90.

Treatment	Days to 50% Silking						
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	83.0 a*	73.8 b	82.0 a	73.0 ab	88.8 b	82.5 a	88.3 a
Chemical kill - April	83.0 a	75.3 a	83.5 a	73.0 ab	90.5 ab	82.3 a	89.0 a
Chemical kill - May	83.5 a	76.0 a	83.5 a	73.8 a	90.5 ab	83.5 a	89.0 a
Moldboard Plough - November	80.0 a	73.0 b	79.3 b	72.5 b	91.5 a	82.8 a	87.8 a
Moldboard Plough - April	79.8 a	73.0 b	78.3 b	73.0 ab	90.3 ab	81.8 a	89.8 a
Chisel Plough - November			82.0 a	72.5 b	90.0 ab	82.5 a	90. a
Chemical kill - September	81.0 a	75.3 a					
Coefficient of variation	3.8	1.3	1.8	1.0	1.9	1.5	3.5

* Values within the same column followed with the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

iv) Corn Plants Harvested

There was no significant difference between the treatment plots in the number of plants hand harvested at site 6 (Table 13). The values varied considerably at site 5 with the chemical kill (October, April and May) and October moldboard treatment plots having significantly more plants (49213 to 53806 plants/ha) than the April moldboard plough treatment plots (38451 plants/ha). The chisel plough treatment plots recorded an average of 47244 plants/ha.

v) Corn Grain Yield and Moisture Content

Where the data were combined over locations (based on treatment six) the treatment by location interaction was not significant for grain moisture content at sites 1 and 2 and sites 3 to 6. This interaction was also not significant for the corn grain yield at sites 1 and 2 only, thus signifying that the treatments had the same effect on these two parameters over the specified locations (Table 3).

Table 13: Mean Corn Plant Population at Harvest for the Red Clover Cover Crop Studies Located in Huron County, 1990.

Treatment	Corn Plant Population at Harvest (plants/ha)	
	Site 5	Site 6
Chemical kill - October	50525 a*	58136 a
Chemical kill - April	50525 a	61690 a
Chemical kill - May	49213 a	61417 a
Moldboard Plough - November	53806 a	61417 a
Moldboard Plough - April	38451 b	61417 a
Chisel Plough - November	47244 ab	62492 a
Coefficient of Variation	13.9	7.2

* Values within the same column followed with the same letter are not significantly different ($p \leq 0.05$) according to the LSD test.

At sites 1 and 2, the mechanical kill treatment plots had lower grain moisture content at harvest than the chemical kill treatment (Table 14). Among the chemical treatments the fall (September and October) treatment plots had a significantly lower amount of corn grain moisture than the spring (April and May) treatment plots. There was no significant difference for the corn grain moisture content among the treatments for sites 3 to 6 (Table 15). At site 7 the average moisture content for the mechanical treatment plots was significantly higher than the average moisture content for the chemical treatment plots with average values of 28% and 25.9%, respectively (Table 15).

A significant treatment effect on corn grain yield was observed at sites 1 and 2 as shown in Table 14. Contrasts show that the corn yielded consistently lower where chemical kill treatments were used compared to the mechanical methods. There was a 11.1% yield increase on the moldboard treatment plots over the chemical treatment plots. It is important to note that moldboard treatment plots had the greatest yield followed by the chemical kill treatment in descending order beginning with the earliest date of application (i.e. September). The April chemical treated plots yielded significantly more than the May chemical treated plots.

Overall, site 5 and 7 recorded the lowest corn grain yields (Table 16). As stated previously, site 5 experienced reduced corn emergence and slower growth rates as a result of soil

crusting which may have affected the final yield. Even though corn plant populations and growth rates were similar to sites 3, 4, and 6, the yield at site 7 may have been affected by the previous crop (2nd year red clover mixture hay field).

No significant differences were reported for the corn grain yield for sites 4, 6 and 7 (see Table 16). Contrasts indicate that there were significant differences between the average of the mechanical treatment yields and the chemical treatment yields at sites 3 and 5 (Table 16). The mechanical treatment plots out yielded the chemical treatment plots by approximately 11% at site 3. The opposite occurred at site 5 where the chemical treatment plots (6.38 Mg/ha) had a higher average yield than the mechanical treatment plots (5.94 Mg/ha) which may have been a result of the low spring moldboard treatment plot yields reducing the average mechanical treatment plot yields.

The chisel plough treatment plots were generally found to produce yields between the fall and spring moldboard treatment plots.

Table 14: Mean Corn Grain Yield and Corn Grain Moisture Content at Harvest Combined Over Locations for Those Sites Having the Chemical Kill in September as Treatment Six (Sites 1 and 2). Red Clover Cover Crop Study, 1987-90.

Treatment	Corn Grain Yield (Mg/ha)	Corn Grain Moisture Content (%)
Chemical kill - October	7.65	31.8
Chemical kill - April	7.62	33.2
Chemical kill - May	7.13	34.1
Moldboard plough - November	8.52	30.7
Moldboard Plough - April	8.25	30.5
Chemical kill - September	7.78	32.0
Probability that the Difference Between Means of Specified Orthogonal Contrasts is Zero		
Fall vs Spring moldboard	NS	NS
Mechanical vs. Chemical kill	**	**
April vs. May Chemical kill	**	NS
September vs. October chemical kill	NS	NS
Fall vs. Spring chemical kill	NS	**

*,** Significant at the 0.05 and 0.01 levels of probability respectively.
NS Not significant at the 0.05 level of probability.

Table 15: Mean Corn Grain Moisture Content for Those Sites Having the Chisel Plough as Treatment Six. Red Clover Cover Crop Study, 1987-90.

Treatment	Corn Grain Moisture Content (%)	
	Sites 3-6	Site 7
Chemical kill - October	30.1	25.7
Chemical kill - April	30.1	25.4
Chemical kill - May	30.1	26.6
Moldboard plough - November	33.3	27.8
Moldboard Plough - April	29.6	27.4
Chisel plough - November	30.5	28.8
Probability that the Difference Between Means of Specified Orthogonal Contrasts is Zero		
Fall vs Spring Moldboard	NS	NS
Moldboard vs. Chisel Plough	NS	NS
Fall vs. spring Chemical kill	NS	NS
Mechanical vs. Chemical kill	NS	*
April vs. May Chemical kill	NS	NS

*,** Significant at the 0.05 and 0.01 levels of probability.
NS Not significant at the 0.05 level of probability.

Table 16: Mean Corn Grain Yield for Those Site Having the Chisel Plough as Treatment Six. Red Clover Cover Crop study, 1987-90.

Treatment	Corn Grain Yield (Mg/ha)				
	Site 3	Site 4	Site 5	Site 6	Site 7
Chemical kill - October	8.25	9.42	6.11	9.45	6.51
Chemical kill - April	7.88	9.99	6.79	9.95	6.35
Chemical kill - May	7.71	9.59	6.25	9.98	6.66
Moldboard Plough - November	8.51	10.12	6.32	9.15	6.19
Moldboard Plough - April	9.34	9.43	5.32	10.16	6.49
Chisel Plough - November	8.62	9.41	6.18	9.64	6.22
Probability that the Difference Between Means of Specified Orthogonal Contrasts is Zero					
Fall vs Spring Moldboard	NS	NS	NS	NS	NS
Moldboard vs. Chisel Plough	NS	NS	NS	NS	NS
Fall vs. Spring Chemical kill	NS	NS	NS	NS	NS
Mechanical vs. Chemical kill	**	NS	*	NS	NS
April vs. May Chemical kill	NS	NS	NS	NS	NS

*,** Significant at the 0.05 and 0.01 levels of probability respectively.
NS Not significant at the 0.05 level of probability.

5.3 Discussion

During the growing seasons of the three year study period (1987-1990) the weather conditions were extremely variable when compared to the 30 year average. For example, in the spring and early summer of 1988 drought conditions existed at all sites. During June precipitation averaged approximately 20% of what may normally be expected. In July of 1989 the amount of precipitation received at either site was less than 5% of the 30 year average while in August precipitation totals were 50% of what would normally be expected. The amount of precipitation received in May of 1990 averaged 139% of the 30 year average, a factor which may have affected plant stand (especially with spring moldboard treatment). From June through November of 1990, with the exception of August, precipitation levels were above the expected levels. As a result, the magnitude of the treatment differences found in the study was probably affected by the extreme moisture conditions. Mean monthly temperatures at all sites were not generally very different from the previous 30 year average.

Throughout the duration of the study no management conditions occurred which would unduly influence the results. It should be noted however that site 7 was located on a second year red clover hay field as opposed to a first year red clover crop underseeded in cereal as were the remaining sites. As a result site 7 had a lower population of red clover plants and a greater population of other hay species. Also of importance is that at site 4 (year 2) the red clover population was somewhat lower than the other underseeded sites as a result of a poor catch due to weather conditions.

In general, the mechanical kill treatments using the moldboard plough appeared to result in grain yields 11% higher than those achieved with the average no-till treatments, although the effect was not always statistically significant. However, the amount of soil residue cover left after planting was unacceptable from an erosion control standpoint since residue cover averaged only 10%. The chemical kill treatments provided somewhat lower corn grain yields with excellent residue cover remaining after planting. The mechanical kill treatment using the chisel plough produced yields which were similar to the October chemical kill treatments and may be used as an alternative to using the moldboard plough.

At sites 3-7 the amount of residue left on the soil surface after spring runoff was 50% or greater for the chisel plough treatment but varied between 3% and 57% residue after planting. The differences in the after planting residue levels for this treatment as well as other treatments may be attributed to various secondary tillage carried out by cooperators

(conventional plots only) moisture conditions (which affect rate of red clover decomposition) and timing of data collection.

One reason for the corn grain yields from the mechanical kill treatment plots surpassing the chemical kill treatment plots may lie in the allelopathic effect of the cereal stubble (especially winter wheat) and/or red clover on the corn. This condition would be more evident on the no-till plots (chemical control of the red clover) than on the conventionally tilled plots. Also insect damage, mainly slugs, was more prevalent on the no-till plots than on the conventionally tilled plots thus reducing corn plant vigour within these treatment plots.

As expected, dry matter collected from each of the treatment plots was related to the date and method of control of the red clover. The chemical treatment applied in May recorded the greatest amount of dry matter after planting followed by the April timing whereas the least amount (if any) was collected on the moldboard plough treatments.

Results of the rainfall simulation indicated that the mechanical kill treatments (moldboard and chisel plough) recorded significantly higher runoff volumes, soil losses as well as total phosphorus losses compared to either of the chemical kill treatments (October or April). The difference in the results obtained for the chemical kill treatments for the above parameters were not significant indicating that the timing of the red clover kill did not affect the erosion control capabilities of these treatments. In addition, no significant differences between the chisel and moldboard plough treatments were reported for these parameters.

6.0 CONCLUSIONS

In general, the use of a no-till red clover cover crop was found to decrease corn grain yields especially when underseeded tinto winter wheat relative to the traditional practice of moldboard ploughing, but not always at a statistically significant level.

The results of the rainfall simulation indicate that the use of chemical methods to decrease soil loss, runoff volume and total phosphorus loss was significantly better than mechanical tillage methods.

7.0 RECOMMENDATIONS

1. In a no-till system it is recommended that the red clover cover crop that is underseeded in a cereal crop be killed by means of a chemical application in October rather than spring. This method will provide adequate soil surface residue cover and soil structural stability to provide excellent erosion control, although corn grain yield may be slightly lower than that after fall moldboard.

2. For soil types or farms where no-till is not feasible, chisel ploughing may be superior to moldboard ploughing to increase the soil surface residue level.

3. To monitor the amount of nitrate nitrogen available to corn contributed to the soil from each of the treatments along with a cost analysis of each treatment.

4. To implement side-by-side field scale studies on land with various textures and slopes that have been underseeded with red clover in a cereal crop using the October chemical treatment, fall chisel and moldboard plough (control) treatments to demonstrate the erosion capabilities of each treatment.

5 To study planter attachments that may result in improved corn performance in a no-till system.

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APPENDIX A

WEATHER SUMMARIES

MAXIMUM, MINIMUM, MEAN DAILY TEMPERATURES FOR BRUCEFIELD
(near sites 1, 2 and 6)

		1987	1988	1989	1990	Brucefield 1951-1980
January	Min (°C)		-2.5	1.2	1.7	-2.7
	Min (°C)		-9.9	-6.1	-4.8	-10.4
	Mean (°C)		-6.2	-2.4	-1.6	-6.6
February	Max (°C)		-2.7	-3.5	0.0	-2.0
	Min (°C)		11.6	-10.5	-6.9	-11.1
	Mean (°C)		7.2	-7.0	-3.5	-6.6
March	Max (°C)		3.9	2.7	6.5	2.7
	Min (°C)		-5.9	-6.1	-2.2	-6.0
	Mean (°C)		-1.0	-1.7	2.2	-1.7
April	Max (°C)		11.1	9.4	13.2	11.5
	Min (°C)		1.5	.4	2.6	0.9
	Mean (°C)		6.3	4.9	7.9	6.2
May	Max (°C)		20.9	18.1	16.6	18.4
	Min (°C)		7.8	6.8	5.2	6.0
	Mean (°C)		14.4	12.4	10.9	12.2
June	Max (°C)		25.0	23.4	23.3	23.9
	Min (°C)		9.1	12.5	11.6	11.2
	Mean (°C)		17.1	18.0	17.5	17.6
July	Max (°C)		29.7	28.5*	25.1	26.2
	Min (°C)		16.5	12.3	13.9	13.6
	Mean (°C)		23.1	20.4	19.5	19.9
August	Max (°C)	24.4	26.8	26.2	24.7	25.0
	Min (°C)	14.6	15.7	11.7	13.8	12.9
	Mean (°C)	19.5	21.3	19.0	19.3	19.0
September	Max (°C)	21.4	19.2	20.7	20.0	20.9
	Min (°C)	11.0	12.3	8.8	10.1	9.7
	Mean (°C)	16.2	15.8	14.7	15.1	15.3
October	Max (°C)	11.1	10.4	15.0	13.9	14.5
	Min (°C)	2.9	3.8	4.7	4.7	4.7
	Mean (°C)	7.0	7.1	9.8	9.3	9.6
November	Max (°C)	7.3	7.6	4.9	8.7	6.8
	Min (°C)	0.3	1.3	-1.7	0.7	-0.3
	Mean (°C)	3.8	4.5	1.6	4.7	3.3
December	Max (°C)	2.3	0.7			0.1
	Min (°C)	-2.5	-6.4			-6.8
	Mean (°C)	-0.1	-2.9			-3.4

* from Clinton Area

DAILY TOTAL PRECIPITATION FOR BRUCEFIELD

(near sites 1, 2 and 6)

		1987	1988	1989	1990	Brucefield 1951-80
January	Rainfall (mm)		29.0	28.0	35.0	23.7
	Snowfall (cm)		21.0	24.0	19.6	68.6
	Total (mm)		50.0	52.0	54.6	92.3
February	Rainfall (mm)		7.0	0.0	28.0	21.7
	Snowfall (cm)		55.6	29.0	23.0	44.1
	Total (mm)		62.6	29.0	51.0	65.8
March	Rainfall (mm)		32.3	19.0	49.0	41.3
	Snowfall (cm)		19.4	10.0	5.0	28.2
	Total (mm)		51.6	29.0	54.0	69.5
April	Rainfall (mm)		66.6	39.0	69.0	69.0
	Snowfall (cm)		3.0	6.0	4.0	5.6
	Total (mm)		69.6	45.0	73.0	74.6
May	Rainfall (mm)		61.0	118.0	92.0	68.6
	Snowfall (cm)		0.0	2.0	0.0	68.6
	Total (mm)		61.0	120.0	92.0	68.6
June	Rainfall (mm)		11.0	66.0	82.0	69.2
	Snowfall (cm)		0.0	0.0	0.0	0.0
	Total (mm)		11.0	66.0	82.0	69.2
July	Rainfall (mm)		62.2	2.8	169.0	74.7
	Snowfall (cm)		0.0	0.0	0.0	0.0
	Total (mm)		62.2	2.8	169.0	74.7
August	Rainfall (mm)	77.3	77.0	36.7*	65.0	77.6
	Snowfall (cm)	0.0	0.0	0.0	0.0	0.0
	Total (mm)	77.3	77.0	36.7	65.0	77.6
September	Rainfall (mm)	98.0	138.5	85.0	140.0	80.7
	Snowfall (cm)	0.0	0.0	0.0	0.0	0.0
	Total (mm)	98.0	138.5	85.0	140.0	80.7
October	Rainfall (mm)	133.0	193.0	86.3	156.0	77.9
	Snowfall (cm)	0.0	0.0	0.0	0.0	0.0
	Total (mm)	133.0	198.0	86.3	156.0	80.6
November	Rainfall (mm)	99.0	116.0	104.0	107.0	66.5
	Snowfall (cm)	50.0	2.0	51.0	2.0	28.2
	Total (mm)	149.0	118.0	155.0	109.0	94.7
December	Rainfall (mm)	52.0	25.0			43.0
	Snowfall (cm)	31.0	53.0			52.1
	Total (mm)	83.0	78.0			95.1

* from Clinton area

MAXIMUM, MINIMUM, MEAN DAILY TEMPERATURES FOR THEDFORD
(near site 3)

		1987	1988	Forest 1951-1980
January	Min (°C)		-1.2	-2.0
	Min (°C)		-8.8	-8.4
	Mean (°C)		-5.0	-5.5
February	Max (°C)		-2.4	-0.5
	Min (°C)		9.7	-8.7
	Mean (°C)		6.1	-4.9
March	Max (°C)		4.3	4.7
	Min (°C)		-4.2	-4.0
	Mean (°C)		0.1	0.2
April	Max (°C)		11.0	12.7
	Min (°C)		1.2	1.9
	Mean (°C)		6.1	7.3
May	Max (°C)		19.7	19.4
	Min (°C)		7.5	7.1
	Mean (°C)		13.6	13.3
June	Max (°C)		24.6	24.7
	Min (°C)		11.0	12.7
	Mean (°C)		17.8	18.7
July	Max (°C)		29.0	27.0
	Min (°C)		16.0	15.6
	Mean (°C)		22.5	21.2
August	Max (°C)	24.8	28.0	26.0
	Min (°C)	14.6	16.0	15.2
	Mean (°C)	19.7	22.0	20.4
September	Max (°C)	21.6	22.0	21.8
	Min (°C)	10.9	10.7	11.8
	Mean (°C)	16.25	16.4	16.6
October	Max (°C)	11.6	11.0	15.8
	Min (°C)	3.3	4.0	6.4
	Mean (°C)	7.45	7.5	11.0
November	Max (°C)	8.0	8.4	7.5
	Min (°C)	1.0	2.1	0.7
	Mean (°C)	4.5	5.3	4.0
December	Max (°C)	2.7		0.9
	Min (°C)	-2.0		-5.5
	Mean (°C)	0.4		-2.4

DAILY TOTAL PRECIPITATION FOR THEDFORD
(near site 3)

		1987	1988	Forest 1951-1980
January	Rainfall (mm)		23.0	20.5
	Snowfall (cm)		11.4	51.6
	Total (mm)		34.4	72.1
February	Rainfall (mm)		7.8	23.2
	Snowfall (cm)		66.6	36.7
	Total (mm)		74.4	59.9
March	Rainfall (mm)		25.8	33.6
	Snowfall (cm)		37.2	22.5
	Total (mm)		68.0	56.1
April	Rainfall (mm)		58.1	75.7
	Snowfall (cm)		0.6	3.8
	Total (mm)		58.7	79.5
May	Rainfall (mm)		32.8	72.3
	Snowfall (cm)		0.0	0.0
	Total (mm)		32.8	72.3
June	Rainfall (mm)		14.0	80.9
	Snowfall (cm)		0.0	0.0
	Total (mm)		14.0	80.9
July	Rainfall (mm)		70.4	90.1
	Snowfall (cm)		0.0	0.0
	Total (mm)		70.4	90.1
August	Rainfall (mm)	99.2	62.8	93.0
	Snowfall (cm)	0.0	0.0	0.0
	Total (mm)	99.2	62.8	93.0
September	Rainfall (mm)	111.5	77.0	81.9
	Snowfall (cm)	0.0	0.0	0.0
	Total (mm)	111.5	77.0	81.9
October	Rainfall (mm)	122.6	120.0	73.2
	Snowfall (cm)	0.0	0.5	0.6
	Total (mm)	122.6	120.5	73.8
November	Rainfall (mm)	99.3	103.5	56.7
	Snowfall (cm)	7.6	0.0	17.0
	Total (mm)	106.9	103.5	73.7
December	Rainfall (mm)	55.2		38.8
	Snowfall (cm)	20.0		36.9
	Total (mm)	75.2		75.7

DAILY TOTAL PRECIPITATION FOR BLYTH
(near sites 4 and 5)

		1988	1989	1990	Blyth 1951-1980
January	Rainfall (mm)		34.5	54.0	23.0
	Snowfall (cm)		38.0	54.0	82.8
	Total (mm)		72.5	108.0	105.8
February	Rainfall (mm)		2.0	40.5	22.7
	Snowfall (cm)		114.0	24.6	44.5
	Total (mm)		116.0	65.1	67.2
March	Rainfall (mm)		23.0	52.0	31.8
	Snowfall (cm)		26.8	20.6	30.9
	Total (mm)		49.8	72.6	62.7
April	Rainfall (mm)		33.3	40.0	61.1
	Snowfall (cm)		50.8	18.6	10.8
	Total (mm)		84.1	58.6	71.9
May	Rainfall (mm)		99.1	103.5	72.7
	Snowfall (cm)		1.0	2.6	1.0
	Total (mm)		100.1	106.1	73.7
June	Rainfall (mm)		99.5	114.5	75.0
	Snowfall (cm)		0.0	0.0	0.0
	Total (mm)		99.5	114.5	75.0
July	Rainfall (mm)		2.0	87.5	76.6
	Snowfall (cm)		0.0	0.0	0.0
	Total (mm)		2.0	87.5	76.6
August	Rainfall (mm)	93.0		78.5	96.3
	Snowfall (cm)	0.0		0.0	0.0
	Total (mm)	93.0		78.5	96.3
September	Rainfall (mm)	138.5	69.0	126.5	88.4
	Snowfall (cm)	0.0	0.0	0.0	0.0
	Total (mm)	138.5	69.0	126.5	88.4
October	Rainfall (mm)	172.0	61.0	150.5	85.0
	Snowfall (cm)	23.5	4.6	trace	5.3
	Total (mm)	195.5	65.6	150.5	90.3
November	Rainfall (mm)	130.5	67.0	147.9	69.4
	Snowfall (cm)	6.0	94.4	20.4	32.0
	Total (mm)	136.5	161.4	168.3	101.4
December	Rainfall (mm)	42.5	15.5		41.6
	Snowfall (cm)	127.0	160.8		74.6
	Total (mm)	169.5	176.3		116.2

MAXIMUM, MINIMUM, MEAN DAILY TEMPERATURES FOR BLYTH

(near sites 4 and 5)

		1988	1989	1990	Blyth 1951-1980
January	Min (°C)		1.0	1.0	-4.3
	Min (°C)		-7.1	-4.4	-11.5
	Mean (°C)		-3.1	-1.7	-7.9
February	Max (°C)		-4.3	0.3	-4.0
	Min (°C)		-10.6	-7.5	-12.3
	Mean (°C)		-7.5	-3.6	-8.2
March	Max (°C)		2.2	4.7	1.4
	Min (°C)		-6.3	-3.4	-7.0
	Mean (°C)		-2.1	0.7	-2.8
April	Max (°C)		9.2	13.1	9.9
	Min (°C)		0.4	2.9	0.3
	Mean (°C)		4.4	8.0	5.1
May	Max (°C)		17.4	15.8	17.6
	Min (°C)		7.2	5.5	6.0
	Mean (°C)		12.3	10.7	11.8
June	Max (°C)		22.1	22.1	22.9
	Min (°C)		12.1	12.3	11.0
	Mean (°C)		17.1	17.2	17.0
July	Max (°C)		27.8	24.2	25.8
	Min (°C)		16.1	14.4	13.5
	Mean (°C)		22.0	19.3	19.7
August	Max (°C)	27.5		24.0	24.7
	Min (°C)	16.0		14.4	12.9
	Mean (°C)	21.8		19.2	18.8
September	Max (°C)	19.2	20.5	19.8	20.5
	Min (°C)	12.3	10.8	10.0	9.7
	Mean (°C)	15.8	15.7	14.4	15.1
October	Max (°C)	8.8	14.4	13.9	13.2
	Min (°C)	3.7	4.3	4.7	4.2
	Mean (°C)	6.3	9.4	9.3	8.7
November	Max (°C)	7.3	4.5	8.4	5.7
	Min (°C)	1.8	-1.7	0.9	-0.7
	Mean (°C)	4.6	1.4	4.7	2.5
December	Max (°C)	-0.5	-7.1		-1.1
	Min (°C)	-6.9	-14.4		-7.5
	Mean (°C)	-3.7	-10.8		-4.3

DAILY TOTAL PRECIPITATION FOR LUCKNOW

(near site 7)

		1987	1988	Blyth 1951-1980
January	Rainfall (mm)		27.2	15.9
	Snowfall (cm)		108.0	107.8
	Total (mm)		135.2	123.7
February	Rainfall (mm)		10.0	17.0
	Snowfall (cm)		192.0	65.6
	Total (mm)		202.0	82.6
March	Rainfall (mm)		23.3	29.2
	Snowfall (cm)		33.0	35.6
	Total (mm)		56.3	64.8
April	Rainfall (mm)		60.5	60.1
	Snowfall (cm)		2.0	10.5
	Total (mm)		62.5	70.6
May	Rainfall (mm)		90.5	69.6
	Snowfall (cm)		0.0	0.9
	Total (mm)		90.5	70.5
June	Rainfall (mm)		19.0	74.6
	Snowfall (cm)		0.0	0.0
	Total (mm)		19.0	74.6
July	Rainfall (mm)		55.7	80.1
	Snowfall (cm)		0.0	0.0
	Total (mm)		55.7	80.1
August	Rainfall (mm)	143.0	97.0	84.9
	Snowfall (cm)	0.0	0.0	0.0
	Total (mm)	143.0	97.0	84.9
September	Rainfall (mm)	94.5	111.0	89.1
	Snowfall (cm)	0.0	0.0	-
	Total (mm)	94.5	111.0	89.1
October	Rainfall (mm)	165.5	219.0	84.1
	Snowfall (cm)	-	9.5	4.9
	Total (mm)	165.5	228.5	89.0
November	Rainfall (mm)	96.5	109.5	69.6
	Snowfall (cm)	28.0	4.0	30.9
	Total (mm)	124.5	113.5	100.5
December	Rainfall (mm)	45.0		35.5
	Snowfall (cm)	31.6		92.8
	Total (mm)	76.6		128.3

MAXIMUM, MINIMUM, MEAN DAILY TEMPERATURES FOR LUCKNOW
(near site 7)

			1987	1988	Forest 1951-1980
January	Min	(°C)		-2.2	-2.6
	Min	(°C)		-10.8	-10.3
	Mean	(°C)		-6.5	-6.5
February	Max	(°C)		-3.0	-1.7
	Min	(°C)		-12.7	-11.1
	Mean	(°C)		-7.9	-6.5
March	Max	(°C)		2.9	3.1
	Min	(°C)		-7.6	-6.5
	Mean	(°C)		2.4	-1.7
April	Max	(°C)		11.0	11.4
	Min	(°C)		0.1	0.4
	Mean	(°C)		5.6	5.9
May	Max	(°C)		21.0	18.4
	Min	(°C)		6.1	5.6
	Mean	(°C)		13.6	12.0
June	Max	(°C)		23.3	23.5
	Min	(°C)		8.4	10.9
	Mean	(°C)		15.9	17.2
July	Max	(°C)		27.9	25.7
	Min	(°C)		14.1	13.6
	Mean	(°C)		21.0	19.7
August	Max	(°C)	24.2	26.0	24.8
	Min	(°C)	13.9	14.6	13.1
	Mean	(°C)	19.1	20.3	19.0
September	Max	(°C)	21.0	20.0	20.6
	Min	(°C)	10.4	9.1	9.6
	Mean	(°C)	15.7	14.6	15.1
October	Max	(°C)	10.4	10.0	14.4
	Min	(°C)	2.3	2.3	4.6
	Mean	(°C)	6.4	6.2	9.5
November	Max	(°C)	7.0	7.0	6.7
	Min	(°C)	-0.3	0.9	-0.3
	Mean	(°C)	3.4	4.0	3.2
December	Max	(°C)	1.3		0.1
	Min	(°C)	-3.2		-6.7
	Mean	(°C)	-1.0		-3.4